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Sturges et al.

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(54) **AUTOMATED CABLE BREAKOUT ASSEMBLY**

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(73) Assignee: **Raytheon Company**, Waltham, MA (US)

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(22) Filed: **Nov. 16, 2015**

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(51) **Int. Cl.**

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B63B 21/56	(2006.01)
H01R 39/64	(2006.01)
B63G 8/42	(2006.01)

(52) **U.S. Cl.**

CPC ***B63B 21/56*** (2013.01); ***B63B 21/04*** (2013.01); ***H01R 39/643*** (2013.01); *B63G 8/42* (2013.01)

(58) **Field of Classification Search**

CPC B63B 21/04; B63B 21/56; B63B 21/66; B63G 8/39; B63G 8/42

USPC 114/230.28, 253

See application file for complete search history.

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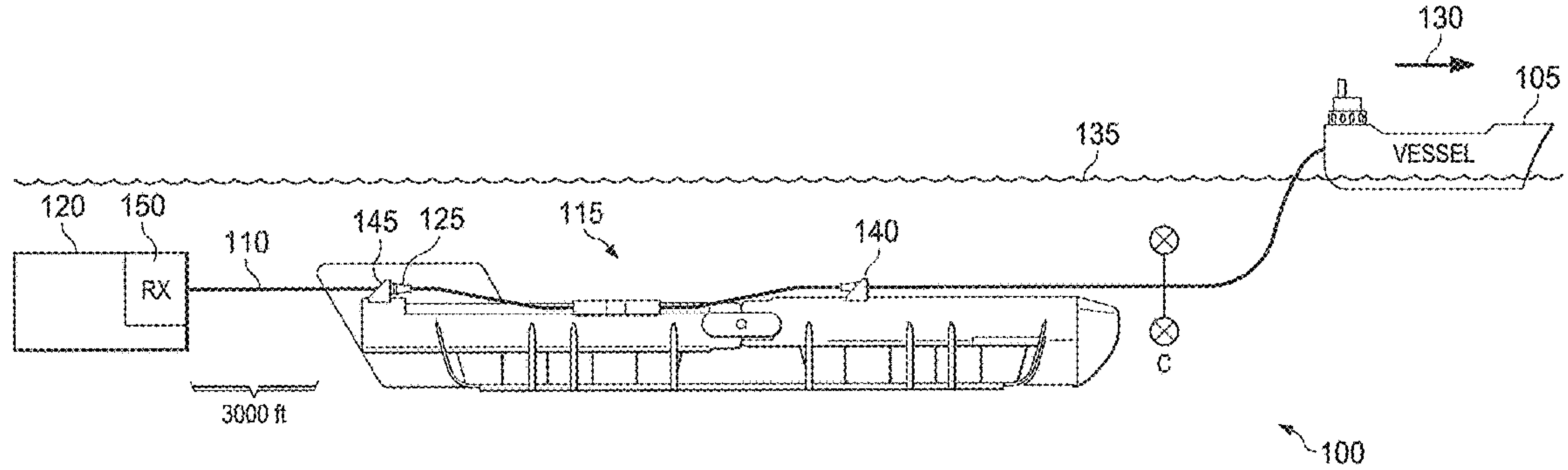
Primary Examiner — Lars A Olson

(57) **ABSTRACT**

A method of engaging an automated breakout assembly includes receiving, by a tow socket having a rotatable sleeve multiple mating connectors, a cable into the tow socket through a slot. The cable comprises a tow ball. Each mating connector is electrically coupled to an electrical conductor. The method includes receiving, by the rotatable sleeve, the randomly-aligned tow ball through an entrance. The method includes rotating a cam configured to rotate the rotatable sleeve to substantially align the mating connectors of the tow socket with connectors of the tow ball such that each electrical conductor electrically coupled to a mating connector couples to a corresponding connector of the tow ball. The method includes transferring a tow loading force between the cable and the tow socket by moving the cable.

20 Claims, 15 Drawing Sheets



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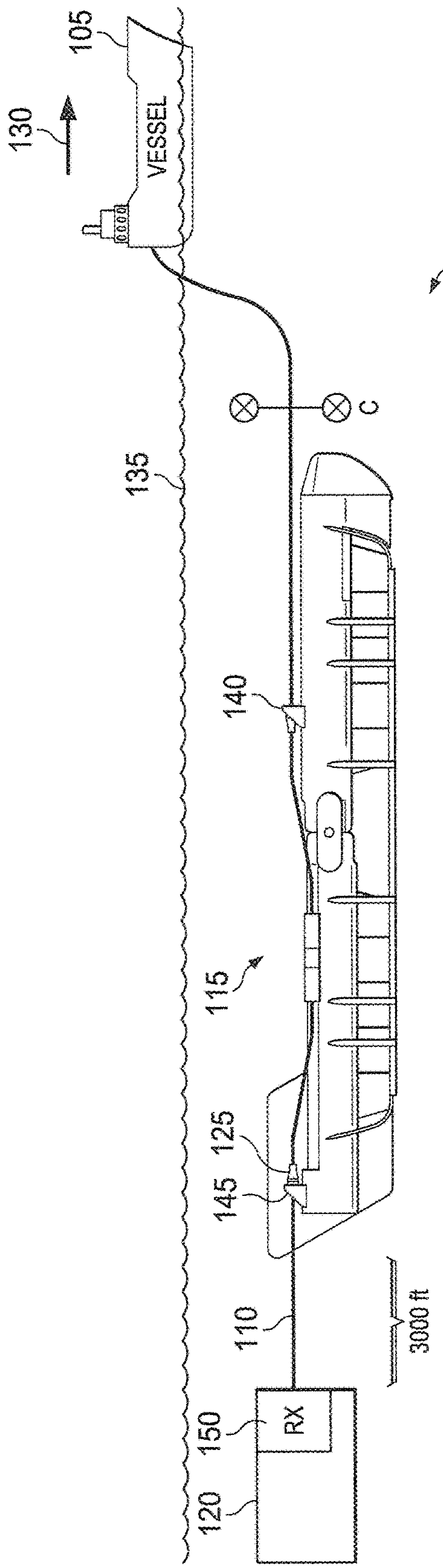


FIG. 1

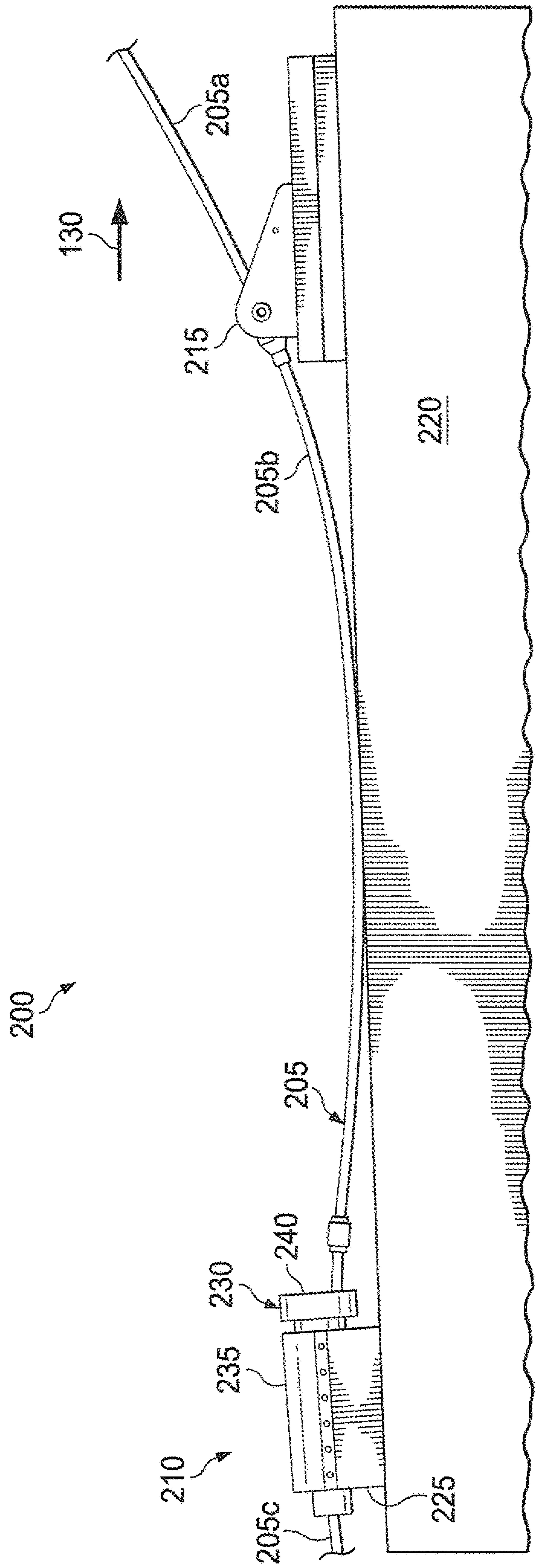


FIG. 2

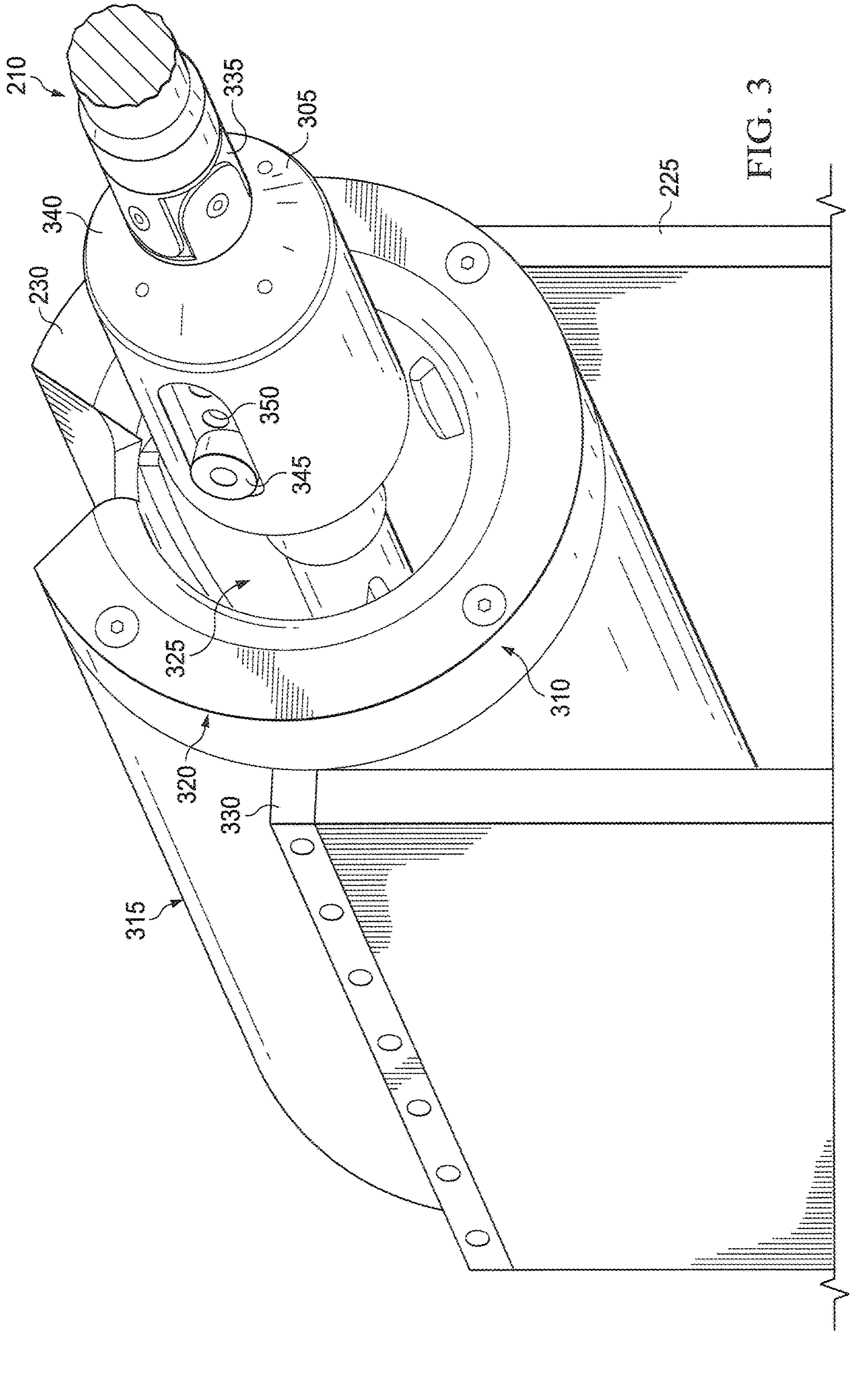


FIG. 3

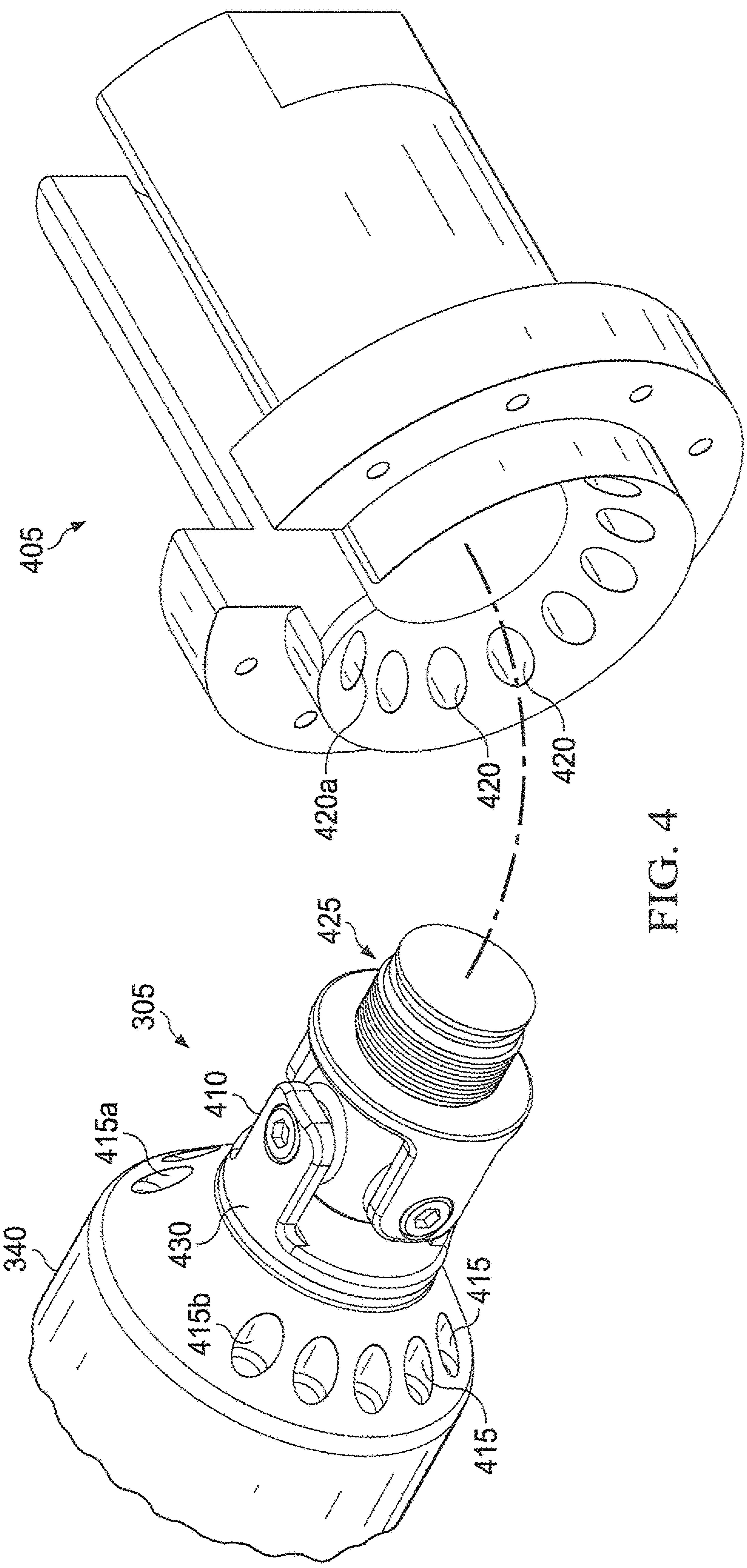


FIG. 4

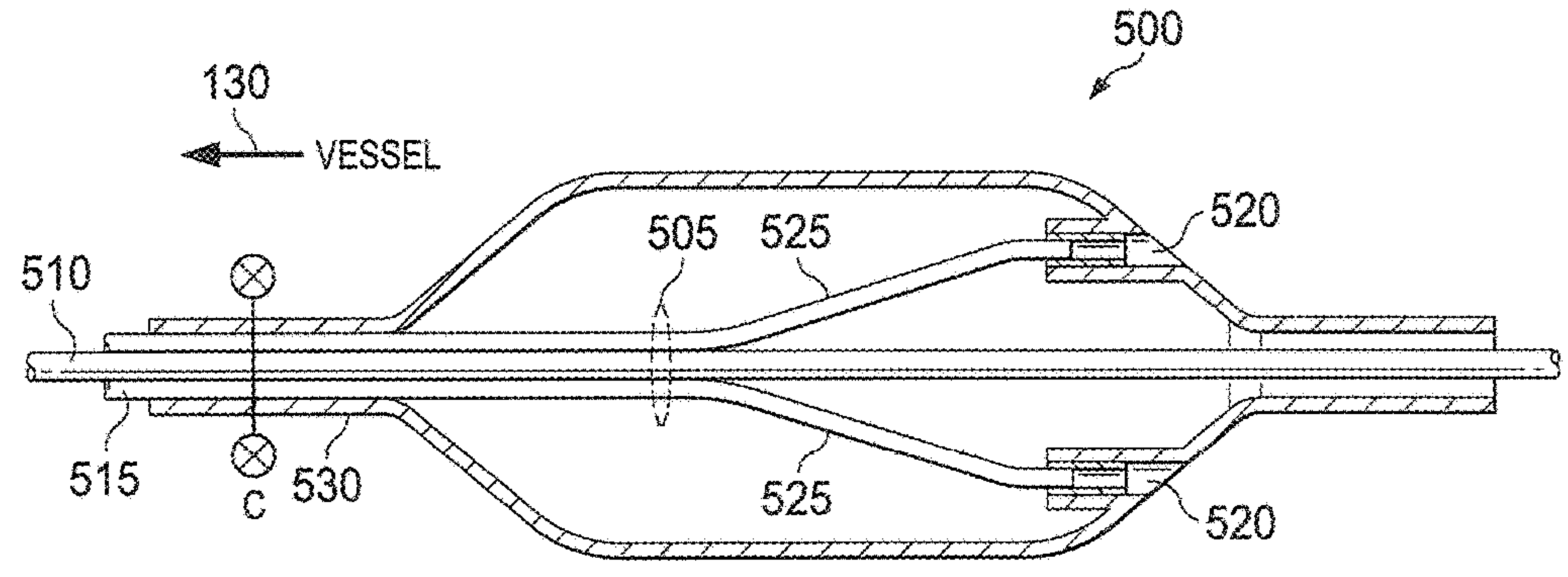

500
130
VESSEL
520
505
525
510
515
C
530
525
520

FIG. 5

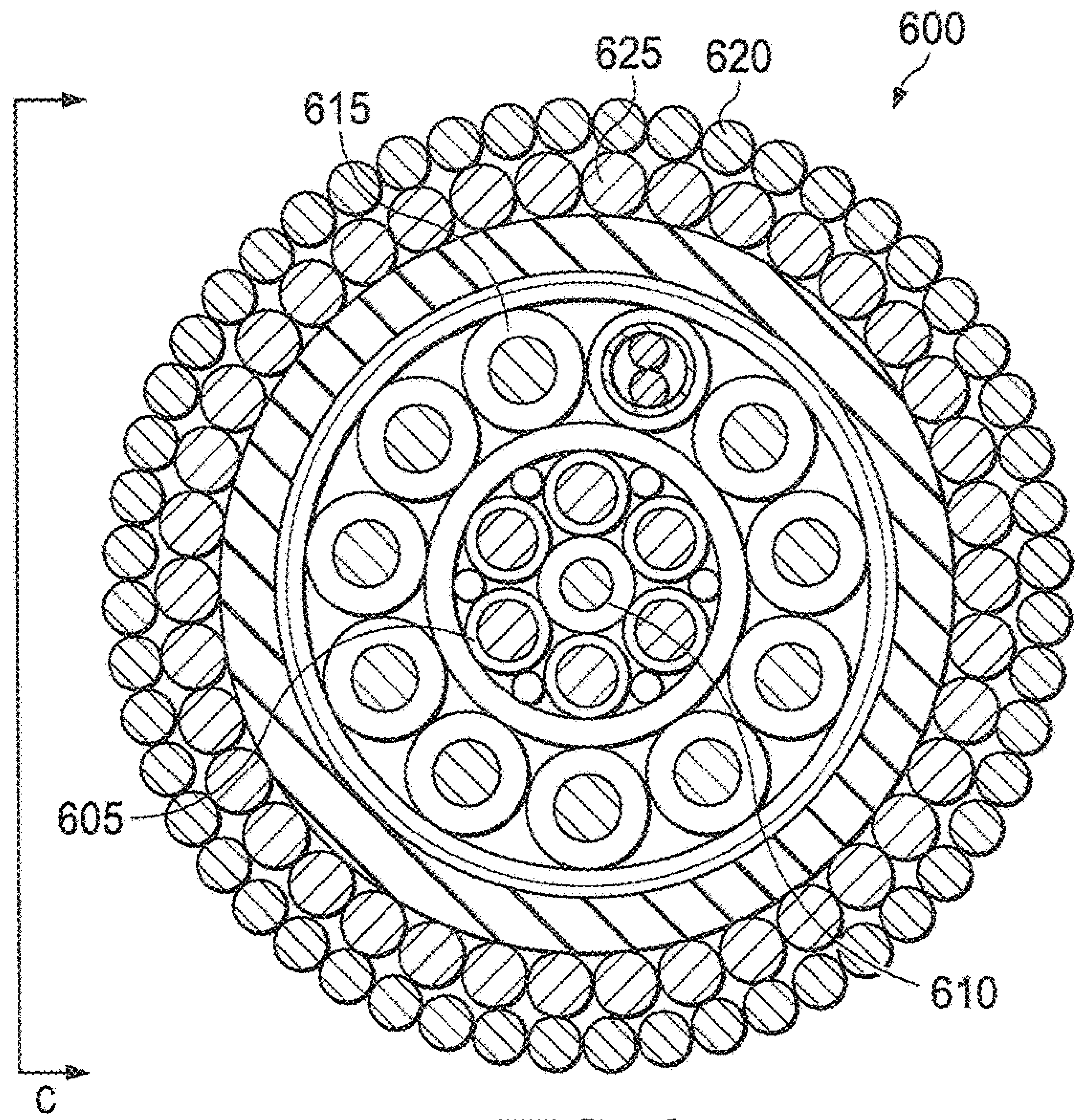

625
620
600
615
605
610
C

FIG. 6

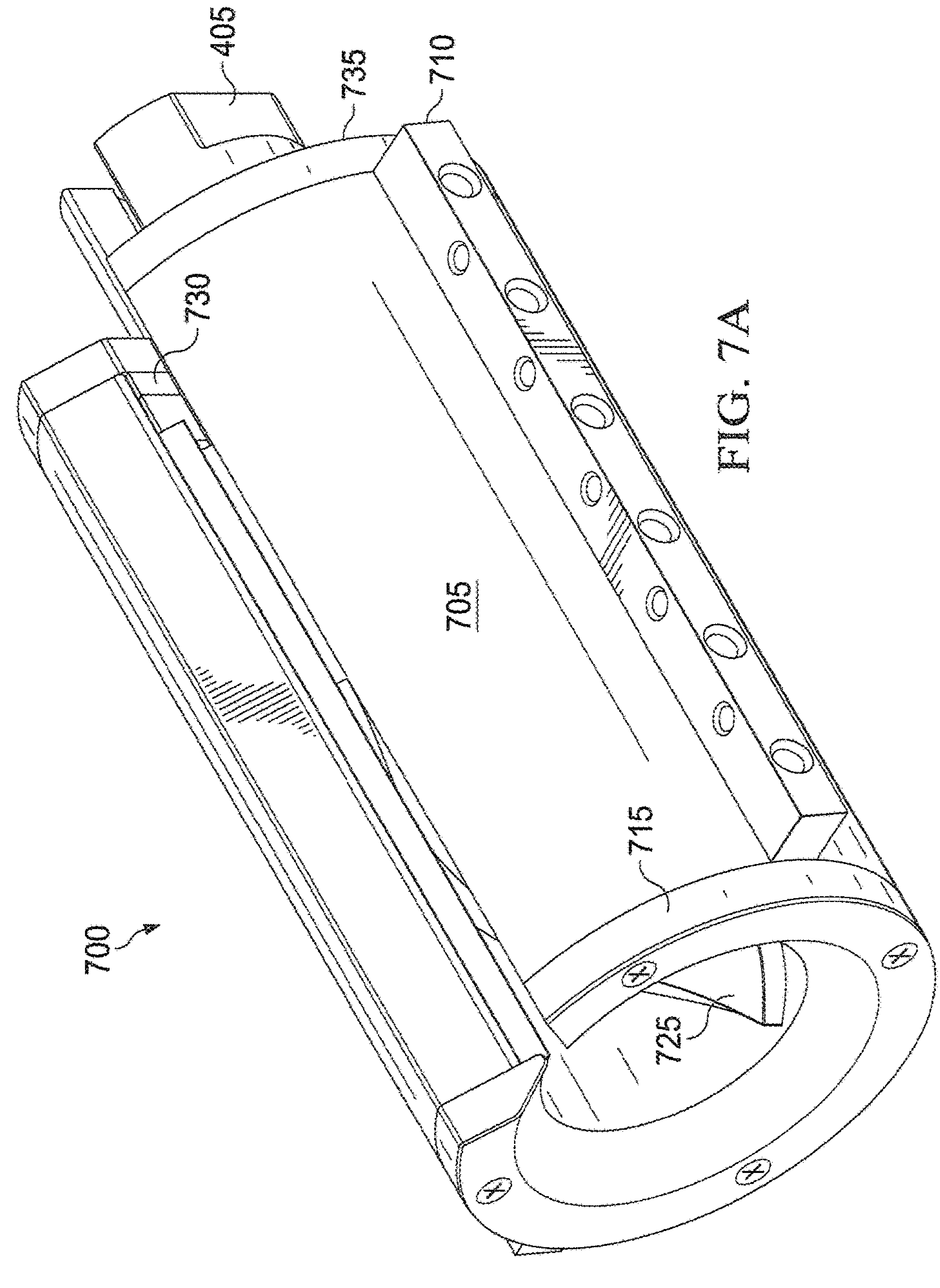


FIG. 7A

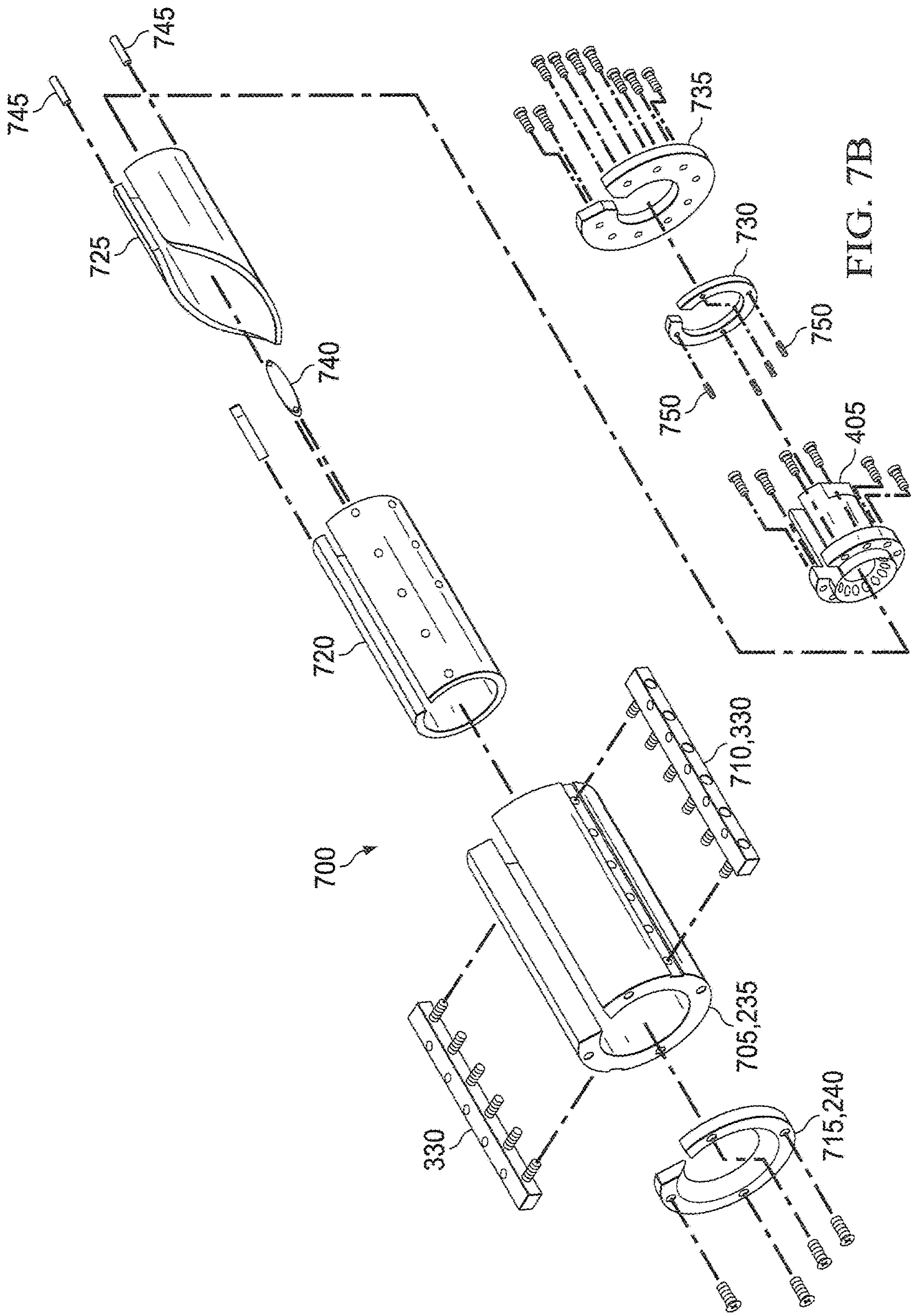

745
745
735
725
730
740
750
750
405
720
710,330
700
705,235
330
715,240

FIG. 7B

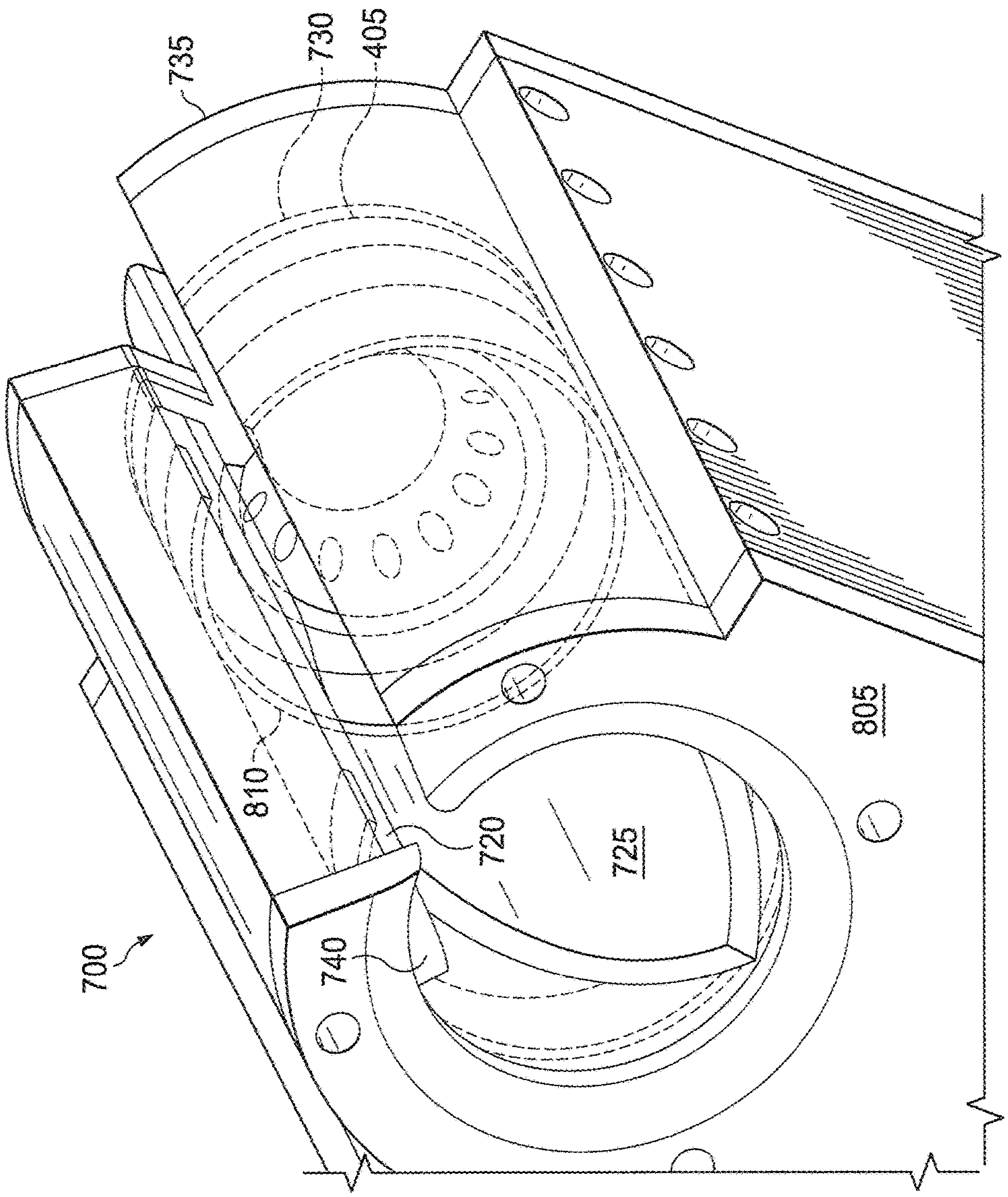
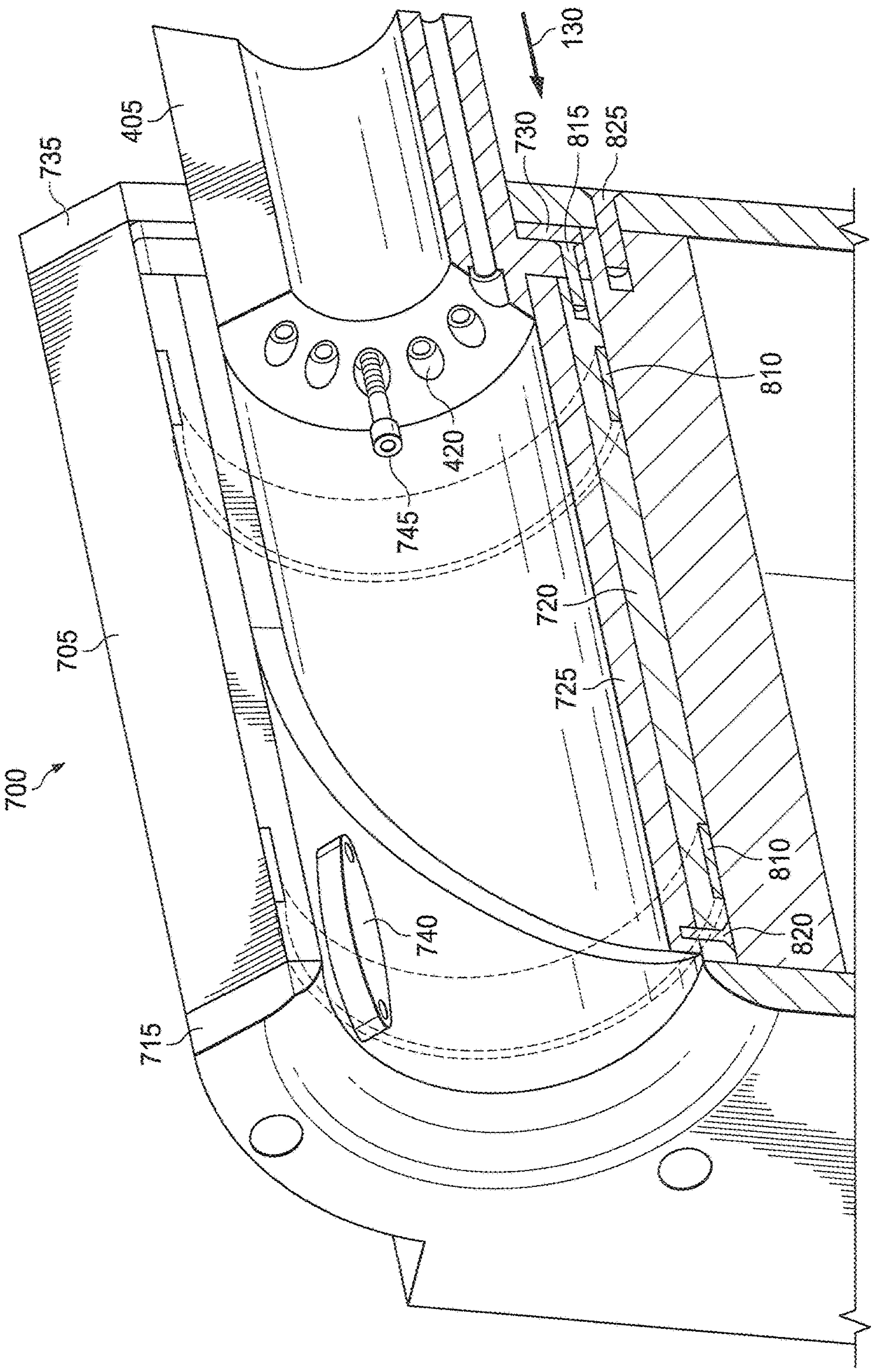


FIG. 8A



130
405
735
730
815
825
810
420
745
720
725
705
700
810
820
740
715

FIG. 8B

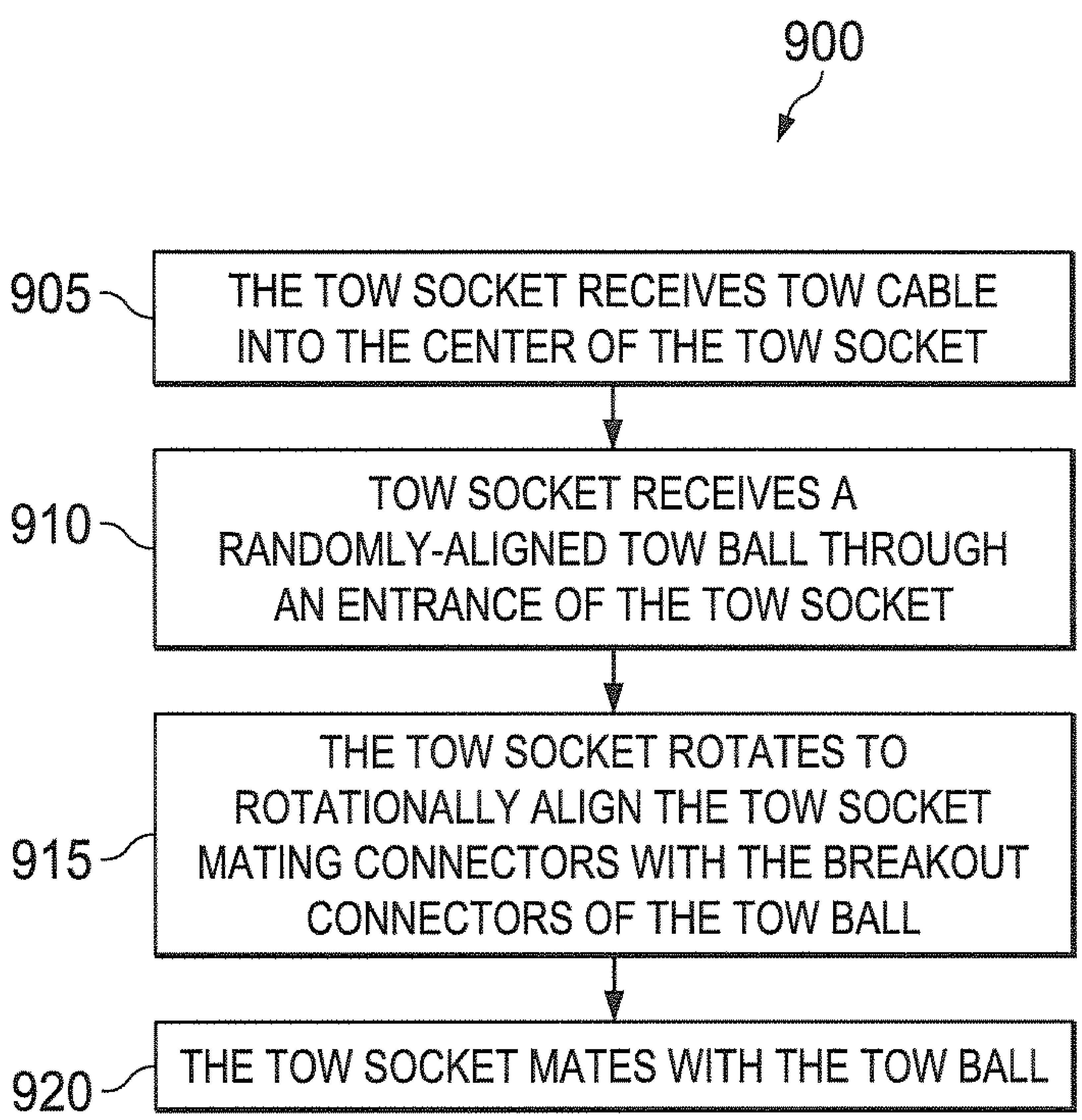

900
905
THE TOW SOCKET RECEIVES TOW CABLE INTO THE CENTER OF THE TOW SOCKET
910
TOW SOCKET RECEIVES A RANDOMLY-ALIGNED TOW BALL THROUGH AN ENTRANCE OF THE TOW SOCKET
915
THE TOW SOCKET ROTATES TO ROTATIONALLY ALIGN THE TOW SOCKET MATING CONNECTORS WITH THE BREAKOUT CONNECTORS OF THE TOW BALL
920
THE TOW SOCKET MATES WITH THE TOW BALL

FIG. 9

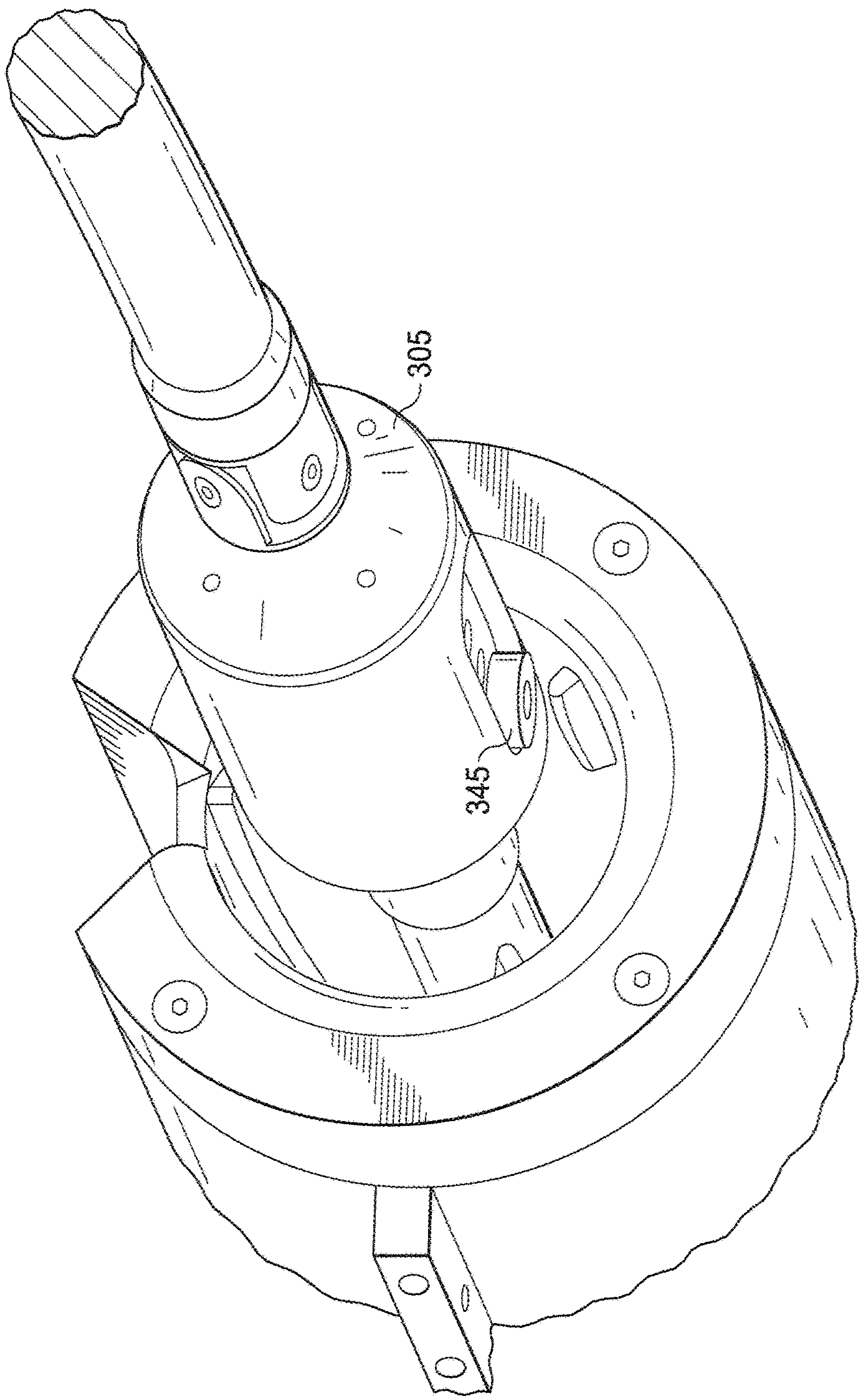


FIG. 10A

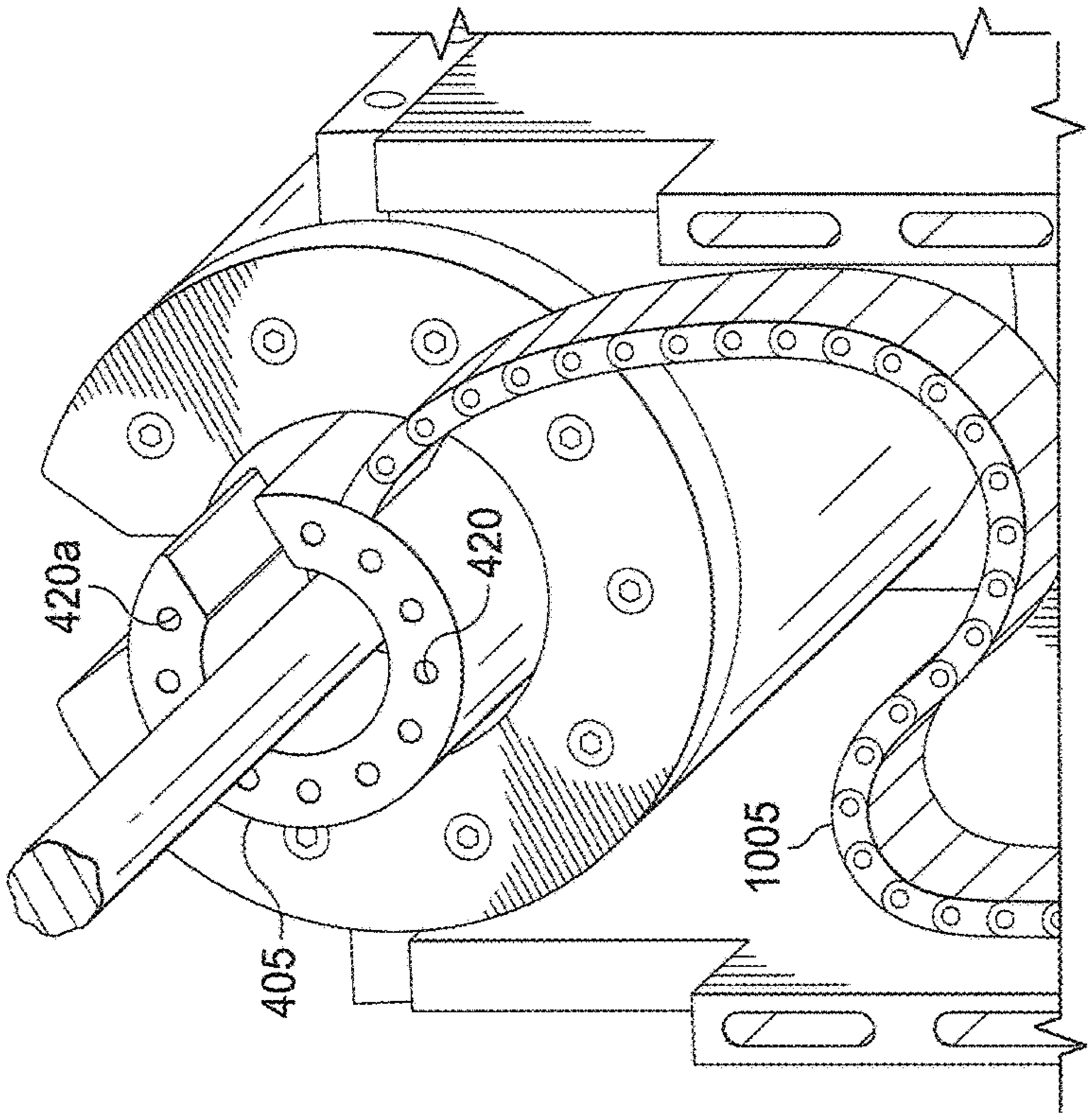


FIG. 11B

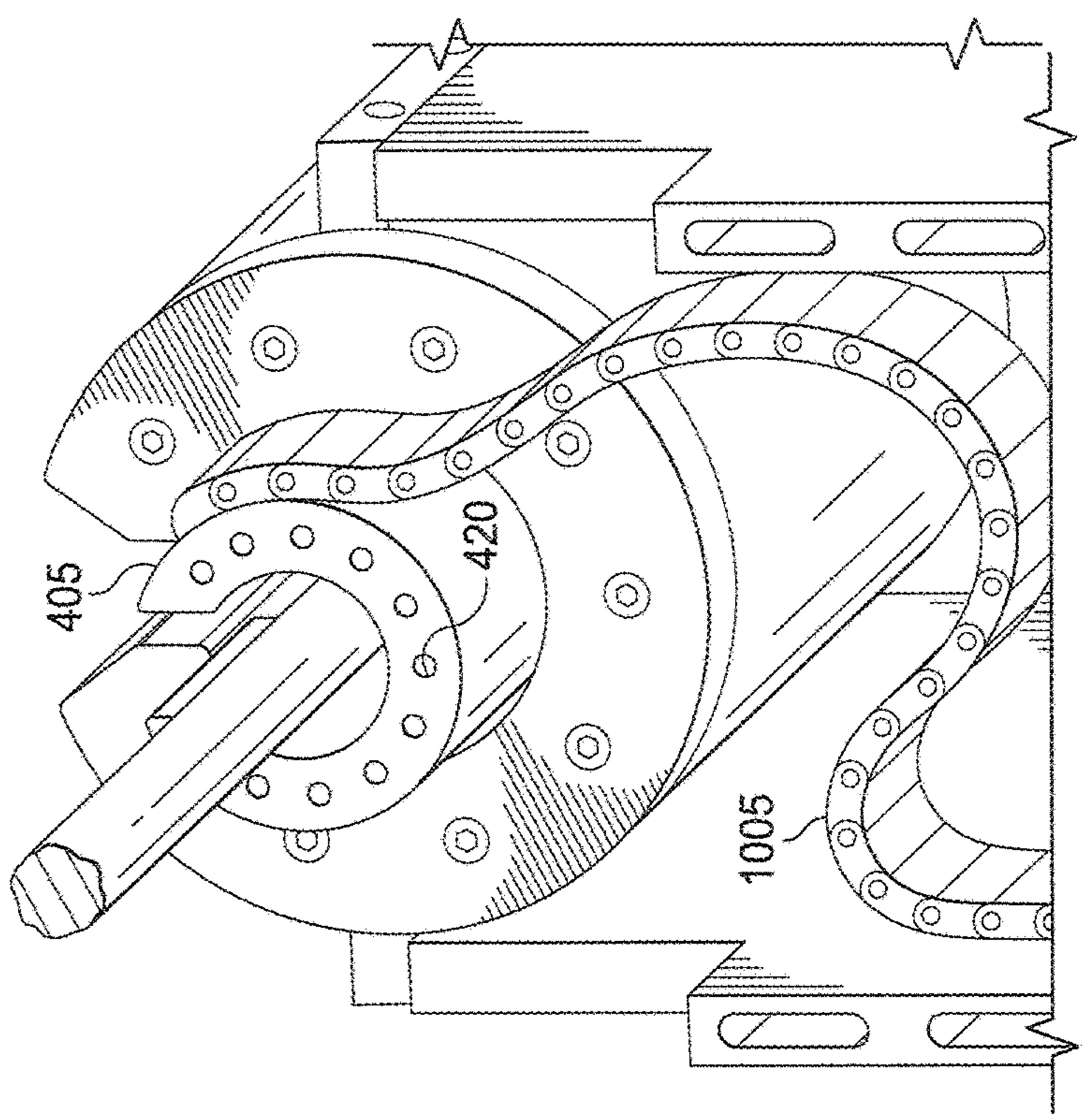


FIG. 10B

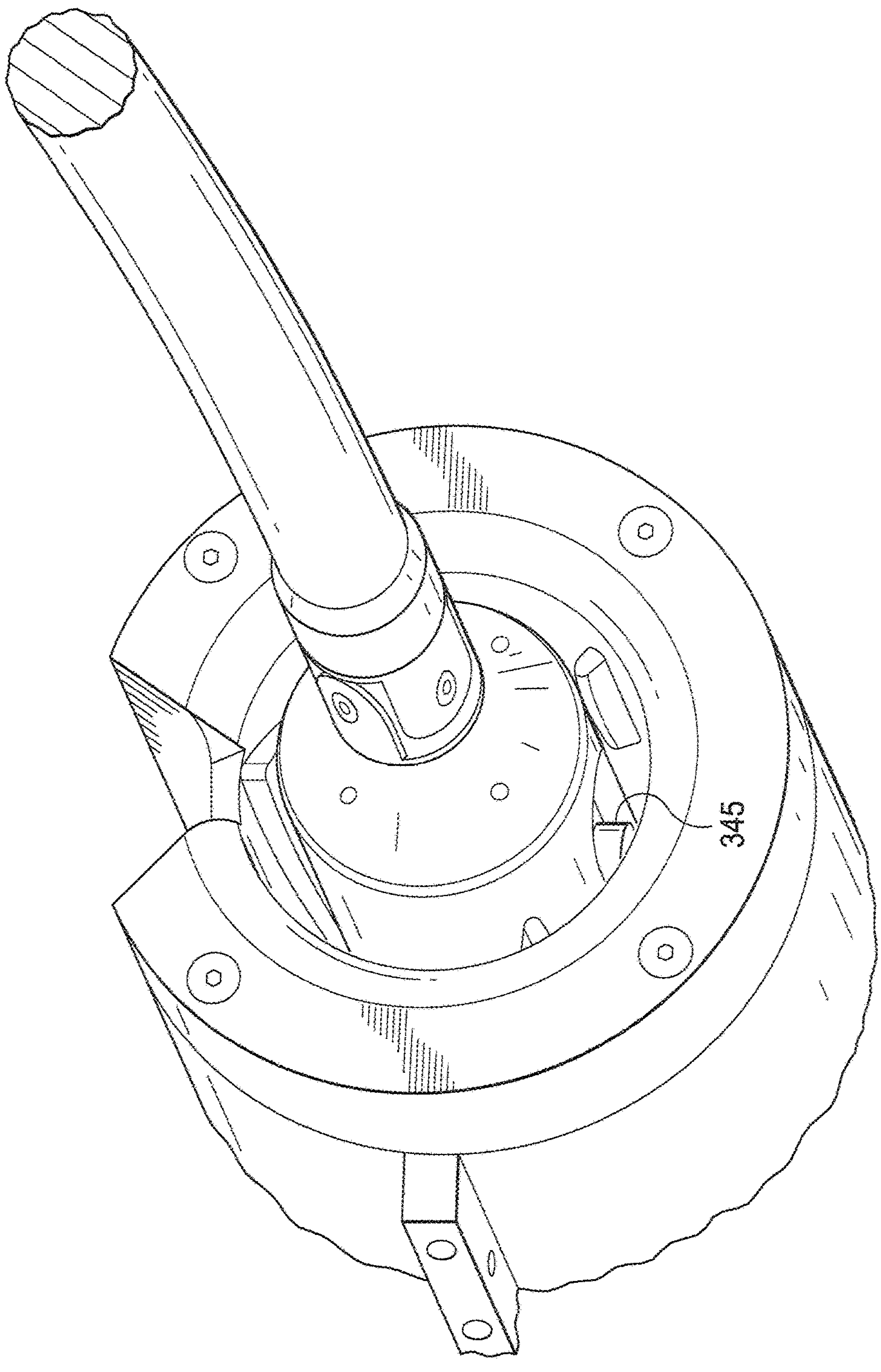


FIG. 11A

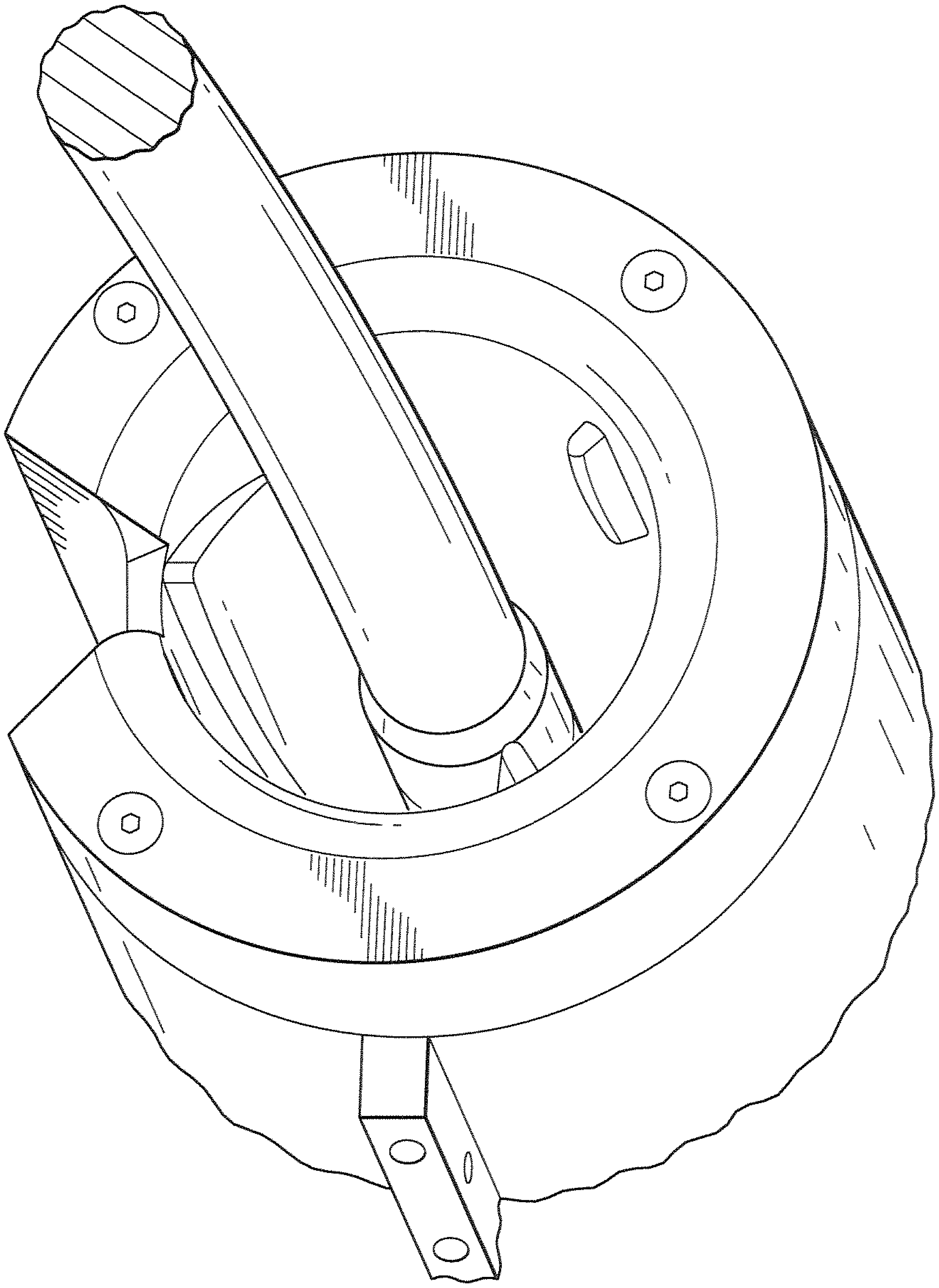


FIG. 12A

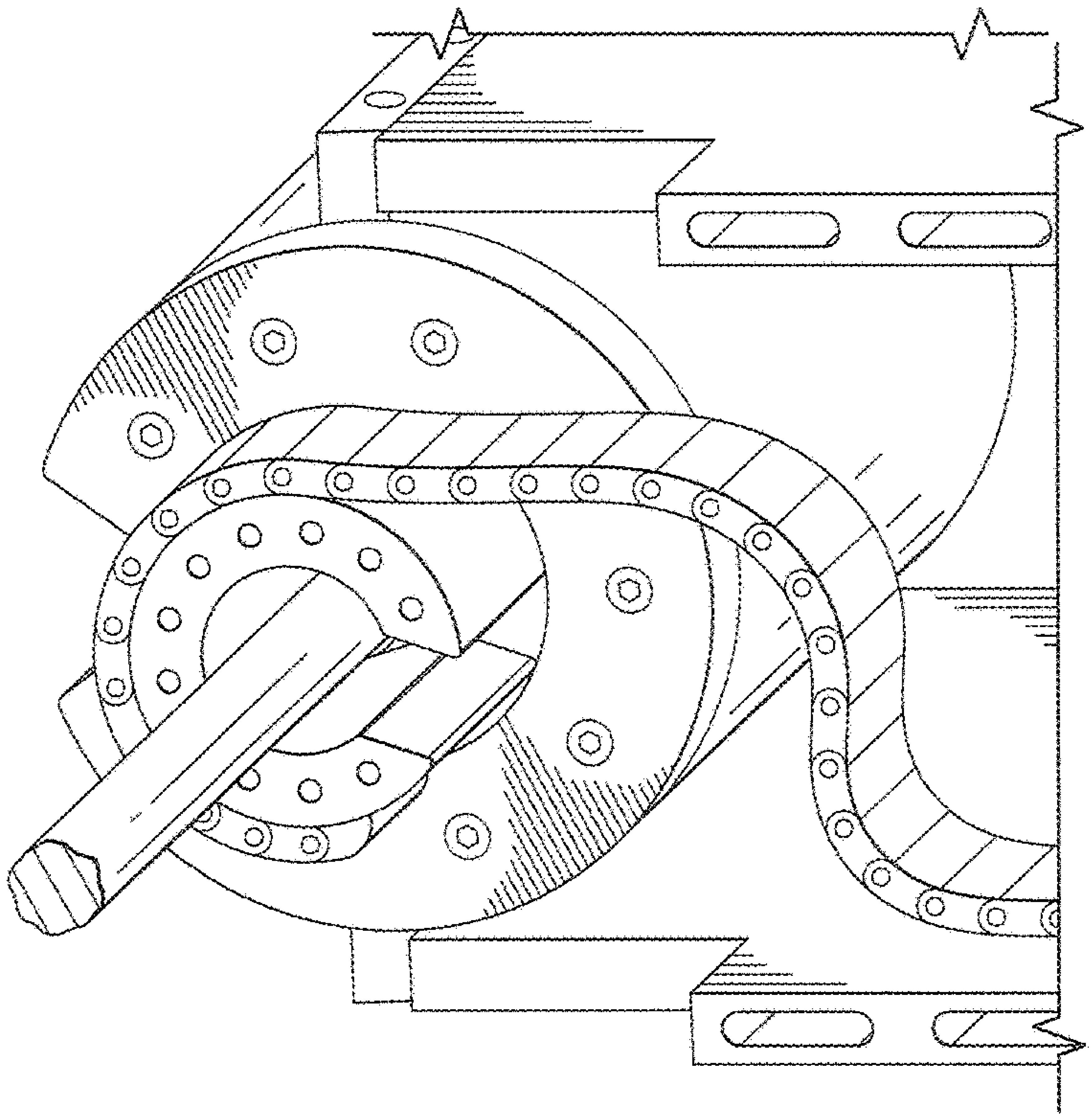


FIG. 12C

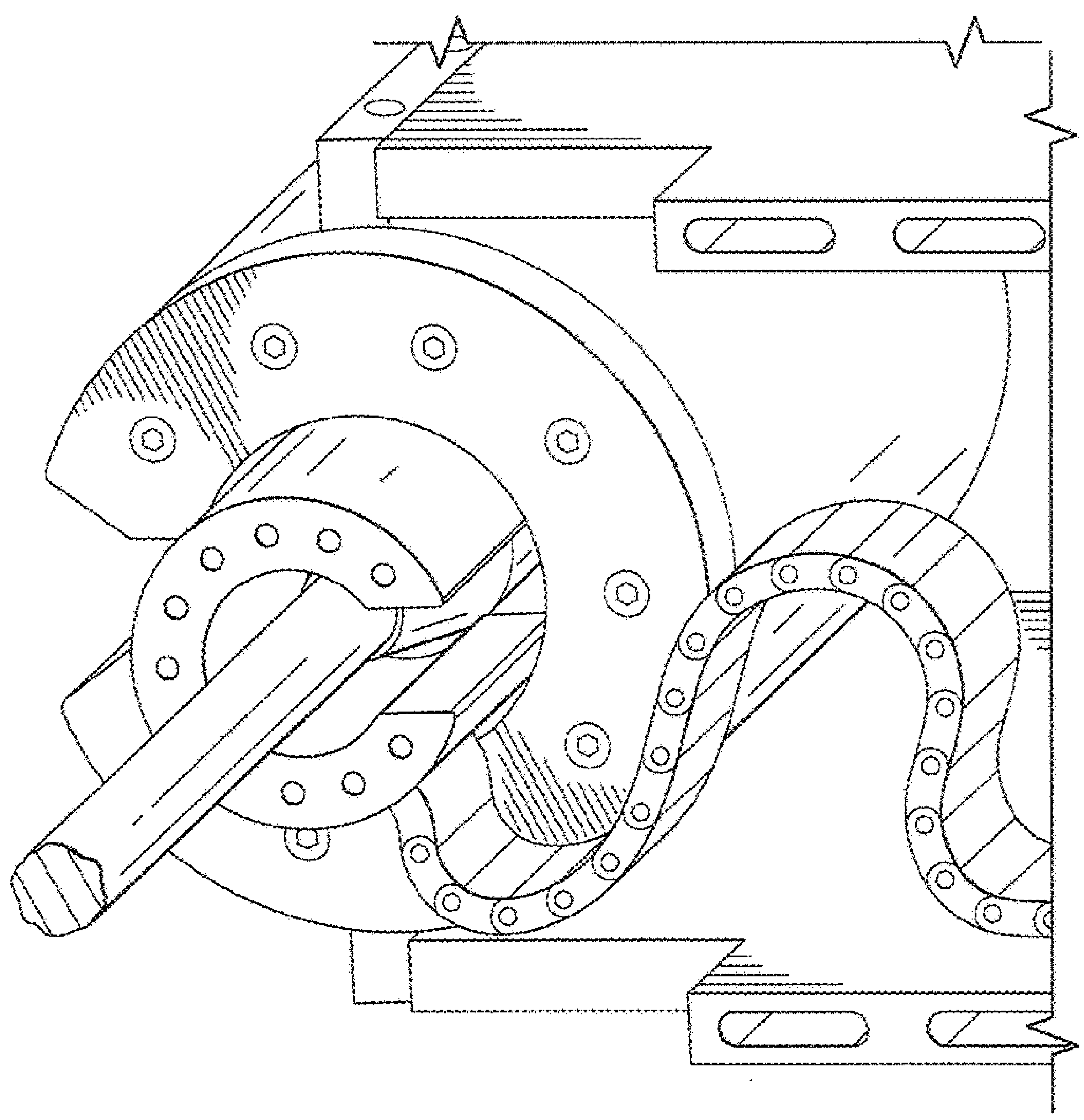


FIG. 12B

AUTOMATED CABLE BREAKOUT ASSEMBLY

CLAIM OF PRIORITY

This application claims priority of U.S. Provisional Patent Application Ser. No. 62/081,935, filed on Nov. 19, 2014, entitled "AUTOMATED CABLE BREAKOUT ASSEMBLY" the teachings of which are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure is directed to towing systems, and more specifically to an automated cable breakout assembly for use with a towing system.

BACKGROUND OF THE DISCLOSURE

In various applications, it may be necessary or desirable to tow multiple vehicles or other bodies behind a vessel. For example, a ship, submarine, or other naval vessel may use multiple bodies to support towed sonar array applications or other applications. As a particular example, one or more towed bodies could include transmit arrays, and one or more other towed bodies could include receive arrays. The transmit arrays generate acoustic signals that reflect off objects and return to the receive arrays. In order to connect multiple bodies to a vessel for towing, separate tow cables are often needed, which increases the complexity and cost of the overall system.

SUMMARY OF THE DISCLOSURE

This disclosure provides an automated breakout assembly (ABA) and method for engaging the ABA.

In a first example, a system includes a body. The body includes a tow socket configured to receive a randomly-aligned tow ball. The tow socket includes a rotatable sleeve, a cam, and multiple mating connectors. Each mating connector is electrically coupled to an electrical conductor. The system further includes a cable configured to be coupled to the body in order to facilitate towing of the body. The cable includes multiple core connectors and multiple breakout connectors configured to transport signals. The cable further includes a tow ball configured to enter the rotatable sleeve of the tow socket. The tow ball includes connectors configured to couple the breakout connectors of the cable to the mating connectors of the tow socket. The cam is coupled to the rotatable sleeve and configured to rotate the rotatable sleeve to substantially align the mating connectors of the tow socket with connectors of a tow ball such that each electrical conductor electrically coupled to a mating connector couples to a corresponding connector of the tow ball.

In a second example, an apparatus includes a tow socket configured to receive a randomly-aligned tow ball. The tow socket includes a rotatable sleeve, a cam, and multiple mating connectors. Each mating connector is electrically coupled to an electrical conductor. The cam is coupled to the rotatable sleeve. The cam is configured to rotate the rotatable sleeve to substantially align the mating connectors of the tow socket with connectors of a tow ball such that each electrical conductor electrically coupled to a mating connector couples to a corresponding connector of the tow ball.

In a third example, a method includes receiving, by a tow socket having a rotatable sleeve and multiple mating connectors, a cable into the tow socket through a slot. The cable comprises a tow ball. Each mating connector is electrically coupled to an electrical conductor. The method includes receiving, by the rotatable sleeve, the randomly-aligned tow ball through an entrance. The method includes rotating a cam to rotate the rotatable sleeve to substantially align the mating connectors of the tow socket with connectors of the tow ball such that each electrical conductor electrically coupled to a mating connector couples to a corresponding connector of the tow ball. The method includes transferring a tow loading force between the cable and the tow socket by moving the cable.

Other technical features may be readily apparent to one skilled in the art from the following figures, descriptions, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which like reference numerals represent like parts:

FIG. **1** illustrates an example of a towing system according to embodiments of the present disclosure;

FIG. **2** illustrates an example of a leading towed body coupled to a tow cable via an automated breakout assembly according to embodiments of the present disclosure;

FIG. **3** illustrates the automated breakout assembly (ABA) of FIG. **2** in a disengaged state;

FIG. **4** illustrates a rear of a tow ball facing a front of a tow ball receiver for clocking and mating according to embodiments of the present disclosure;

FIG. **5** illustrates a longitudinal cross-section of an example tow ball according to embodiments of the present disclosure;

FIG. **6** illustrates a lateral cross-section of an example tow cable according to embodiments of the present disclosure;

FIGS. **7**A and **7**B illustrate an example aft tow point socket according to embodiments of the present disclosure;

FIGS. **8**A and **8**B illustrate a solid assembly view of the tow socket of FIGS. **7**A and **7**B mounted to an aft tow point;

FIG. **9** illustrates a method of engaging an ABA according to embodiments of the present disclosure; and

FIGS. **10**A through **12**C illustrate various operations within the method of engaging an ABA in FIG. **9**.

DETAILED DESCRIPTION

It should be understood at the outset that, although example embodiments are illustrated below, the present invention may be implemented using any number of techniques, whether currently known or not. The present invention should in no way be limited to the example implementations, drawings, and techniques illustrated below. Additionally, the drawings are not necessarily drawn to scale.

This disclosure provides an automated cable breakout assembly that can be used to connect multiple vehicles or other bodies to a vessel using a single tow cable. The automated cable breakout assembly also provides an automated interconnection, meaning little or no human intervention may be required to properly align a towed vehicle or other body to a connector on the tow cable. Further, the automated cable breakout assembly allows for interconnection at any mid-point of a tow cable, meaning signals can be received from or provided to the tow cable at various points between the ends of the tow cable. In addition, implementing the automated cable breakout assembly (ABA) with the design features described herein will reduce or eliminate the risk of cable damage due to mating rotational alignment and/or towed body rotation due to rotational stiffness of the tow cable.

These or other benefits can be obtained via the use of a tow ball that structurally anchors a cable. The tow ball has embedded connectors that rotationally align with mating connectors embedded in a tow socket, which is fixed to a towed vehicle or other towed body. When a randomly-aligned tow ball enters the tow socket, a cam follower of the tow ball drives a rotation cam fixed to a rotation sleeve in the tow socket to achieve rotational alignment. Mating occurs via (drag) tension in the tow cable.

Among other things, example novel features of this approach include the tow socket's rotation sleeve and its peripheral hardware, which allow for automated interconnection without cable damage and/or towed body rotation once the towed vehicle or other body is launched. Other novel features include a low-friction rotation sleeve with its integral cam and embedded socket connectors, plus a flexible cable wired to the connectors in the socket and its return mechanism that re-align the cable entry slots of the outer housing with the inner rotation sleeve.

Additional details regarding one example implementation of the automated cable breakout assembly are provided below. The automated cable breakout assembly could be used in any suitable application, such as in towed array sonar applications or other applications where multiple vehicles or other bodies are towed using a common tow cable. Examples of towed sonar array applications where the automated cable breakout assembly disclosed herein could be used to couple vessels to towed vehicles or other bodies are disclosed in U.S. Pat. No. 6,683,819 and U.S. Pat. No. 7,046,582 (both of which are hereby incorporated by reference). However, the automated cable breakout assembly disclosed here could be used in any other suitable applications, including military and commercial applications. Example applications could include towed array sonar applications for submarine detection, search and rescue operations, underwater navigation, or underwater mapping applications.

FIG. **1** illustrates an example of a towing system **100** according to embodiments of the present disclosure. In the towing system **100**, a vessel **105** tows one or more bodies that communicate signals to each other through a single cable that mechanically tethers the bodies to each other and to the vessel. Various components of the towing system form an automated breakout assembly (ABA) to achieve an electrical breakout interconnection and load transfer between a tow cable **110** and one or more towed bodies **115**-**120**. The towing system **100** includes the vessel **105**, the tow cable **110**, one or more towed bodies **115**-**120**, and at least one ABA **125**. The towing system **100** can include towed bodies connected in series, such that one towed body leads another towed body, and the other towed body trails its leader. In the example shown, the towed body **115** represents a leading towed body, and the towed body **120** represents a trailing towed body. In a specific example, the distance between the leading towed body **115** and the trailing towed body **120** can be several thousand feet.

An auxiliary tow ball at the forward tow point **140** is a component that enables certain functions of the ABA **125** as described herein. The auxiliary tow ball at the forward tow point **140** bears the drag loading of the towed body **115** and all that is towed behind it. This enables the cable between the ABA tow ball (i.e., tow ball within the ABA **125**) and the auxiliary (forward) tow ball to be slack during towing operations and enables the ABA tow ball to remain engaged by the drag force of the trailing towed body **120**.

The vessel **105** tows the towed bodies **115**-**120** in a forward direction **130** by using the tow cable **110**. The vessel **105** can float on the surface **135** of a body of liquid, such as water in an ocean or lake. A host ship is an example of the vessel **105**.

The tow cable **110** tethers the towed bodies **115**-**120** to each other and to the vessel **105**, restricting movement in undesired directions. The tow cable **110** extends from the vessel **105** to various tow points on the leading towed body **115**, and further to a tow point of the trailing towed body **120**. The tow cable **110** is coupled (i.e., connected or mechanically attached) to the vessel **105** and each of the towed bodies **115**-**120**. That is, the tow cable **110** includes one end that is coupled to the vessel **105**, and another end that is attached to the trailing towed body **120**. The tow cable **110** also includes one or more tow balls (described more particularly below) that each form a portion of an ABA **125** for interconnecting any mid-point of the tow cable **110** to a towed body **115**-**120**. The tow cable **110** is a single cable, wherein the line C represents a location for a lateral cross-section of the tow cable **110**. The circle with an "x" through the center represents a direction into the page for the cross-section cut along the line C.

The towing system **100** can be an underwater towing system, wherein the leading towed body **115** and the trailing towed body **120** are submerged during a towing operation. The leading towed body **115** includes a forward tow point **140**, a hull, and an aft tow point **145** to which mid-points of the tow cable **110** connect. The leading towed body **115** includes a transmit array configured to accept a sound navigation and ranging (SONAR) transmit signal from the towing vessel **105** through the tow cable **110**. Correspondingly, the trailing towed body **120** includes a forward tow point to which the end of the tow cable **110** connects, and a receive array **150** configured to transmit SONAR signals to and accept power from the towing vessel **105**.

The zoomed-in portion of FIG. **1** shows the ABA **125** at a closer point of view. In this embodiment, the ABA **125** transfers load between the tow cable **110** and the leading towed body **115**. That is, the ABA **125** is formed from the tow ball of the tow cable **110** and a tow socket of the leading towed body **115**.

Although FIG. **1** illustrates one example of a towing system **100**, various changes may be made to FIG. **1**. For example, the relative sizes, shapes, and dimensions of the various components shown in FIG. **1** are for illustration only. Each component in FIG. **1** could have any other size, shape, and dimensions.

FIG. **2** illustrates an example of a leading towed body **200** coupled to a tow cable **205** via an automated breakout assembly **210** according to embodiments of the present disclosure. For ease of explanation, the leading towed body **200** is described as being used in the towing system **100** of FIG. **1**. However, the leading towed body **200** could be used in any other suitable system.

The leading towed body **200** includes a forward tow point **215**, a hull **220**, an aft tow point **225**, and a transmit array. The ABA **210** is mounted to the aft tow point **225** and is configured to connect the aft tow point **225** to a mid-point of the tow cable **205**. An auxiliary tow ball that is forward-bearing at the forward tow point **215** is a part of the cable **205** and is spaced a distance from the ABA **210** that is greater than the distance between the aft and forward tow points **225** and **215**.

The leading towed body **200** and tow cable **205** could, for example, be used in the towing system **100** of FIG. **1**. For example, the forward direction **130** indicates the direction toward which a vessel, such as the vessel **105**, tows the leading towed body **200**, bearing the drag loading at tow point **215**. Note that components **210**, **215**, **220**, and **225** in FIG. **2** could be the same as or similar to corresponding components **125**, **140**, the hull, and **145** in FIG. **1**. These components in FIG. **2** can operate in the same or similar manner as the corresponding components in FIG. **1**.

The zoomed-in portion of FIG. **2** shows the ABA **210** at a close point of view. As shown, the ABA **210** is in an engaged state, where the tow ball of the tow cable **205** is electrically and mechanically coupled to the tow socket **230** of the leading towed body **200**. The tow socket **230** of the leading towed body **200** includes an outer housing **235** forming a fixed sleeve into which the tow ball of the tow cable **205** can slide into for engaging or slide out of for disengaging the tow ball of the tow cable **205**. The tow socket **230** also includes a front plate **240** fastened to a front of the outer housing **235** and providing a front surface of the tow socket **230**. Internal components of the tow socket **230** include a rotation sleeve, a tow ball receiver that is a component of a tow socket connection assembly, low friction rings, and a cam, each of which are described more particularly below with reference to FIGS. 7B and **8**. In the engaged state, as the tow ball of the tow cable **205** is disposed within the sleeve of the tow socket **230**, the tow ball is hidden from view from the side perspective of FIG. **2**. In the disengaged state, the tow ball of the tow cable **205** is outside of the sleeve of the tow socket **230**, and would be visible from the side perspective of FIG. **2**.

A first portion **205***a* of the tow cable **205** extends from the forward tow point **215** to the vessel. A second portion **205***b* of the tow cable **205** extends from the forward tow point **215** to the tow socket **230**. A third portion **205***c* of the tow cable **205** extends from the tow socket **230** to a tow point of the trailing towed body **120**.

Although FIG. **2** illustrates one example of a towed body **200**, various changes may be made to FIG. **2**. For example, the relative sizes, shapes, and dimensions of the various components shown in FIG. **2** are for illustration only. Each component in FIG. **2** could have any other size, shape, and dimensions.

FIGS. **3** through **12**C illustrate details of the ABA **210** of FIG. **2** according to this disclosure. For ease of explanation, the ABA **210** is described as being a component of the leading towed body **200** that is used in the system **100** of FIG. **1**. However, the ABA **210** could be used in any other suitable system.

FIG. **3** illustrates the ABA **210** of FIG. **2** in a disengaged state. In the disengaged state, the tow ball **305** of the tow cable **205** is outside of the tow socket **230**. In the position shown, the third portion **205***c* of the tow cable **205** is disposed within the tow socket **230**, and the tow ball **305** is positioned to be radially aligned with the sleeve.

In this perspective, namely, forward of the tow socket **230** facing aft, an external surface is shown, including the front surface **310** and side surface **315**, of the tow socket **230**. The external surface of the tow socket **230** has the shape of a circular tube or sleeve with a wedge notch cutout (i.e., slot) at approximately its 12 o'clock position. The wedge notch cutout extends from the front surface **310** to the rear surface of the tow socket **230**. The front surface **310** includes an outer circumference **320** at the external surface of the tow socket **230**, and an inner circumference **325** formed by a hole through the entire length of the tow socket **230**. The inner circumference **325** at the front surface **310** forms an entrance for the tow ball **305** to enter the hole.

The side surface **315** includes the round external surface of the outer housing **235** formed at the outer circumference **320** and a mount rail portion **330** that extends radially outward from the round external surface of the outer housing **235**. The mount rail portion **330** allows bolts to fasten the tow socket **230** to the aft tow point **225** by extending vertically through the mount rail portion **330**. The mount rail portion **330** is fastened to the outer housing **235** by bolts extending horizontally through the mount rail portion **330**. Other methods can be used to attach the tow socket **230** to the aft tow point **225**, such as welding.

The tow ball **305** includes multiple cable interfaces configured to connect to the tow cable **205**. These cable interface components can function separately or as intrinsic protection, strength members, or U-joint-type bend limiters. More particularly, the tow ball **305** includes a forward cable interface **335** to couple to the second portion **205***b* of the tow cable **205**. The tow ball **305** includes a rear cable interface (shown in FIG. **4** by reference number **410**) to couple to the third portion **205***c* of the tow cable **205**. The forward cable interface **335** can be similar to the rear cable interface **410**, namely, including u-joints with a threaded cylinder configured to mate with the second portion **205***b* of the tow cable **205**. That is, the second portion **205***b* of the tow cable **205** can connect to the tow ball **305** via the forward cable interface **335** in a same or similar way that the third portion **205***c* connects with the tow ball **305** via the rear cable interface **410**.

The tow ball **305** includes a ball member **340** between the forward cable interface **335** and rear cable interface **410**. The ball member **340** can have the shape of a cylinder with a front and rear truncated cone on each of its bases (as shown in FIG. **3**), or another suitable shape that complements the shape of the internal components of the tow socket **230**. The cylinder portion of the ball member **340** includes cam follower **345** disposed within a recess. The cam follower **345** can be a flat head pin that fits into the pin holes **350** within the recess. The pin head of the cam follower **345** protrudes radially outward from the cylinder portion of the external surface of the ball member **340**. When the cam follower **345** enters the tow socket **230**, the pin head of the cam follower **345** contacts an internal surface of a rotation cam (shown in FIGS. **7**A and **7**B by reference number **725**), thereby initiating a clocking operation. That is, movement of the tow cable **205** in a direction of the longitudinal axis of the ABA **210**, such as during a winching operation, causes the tow ball **305** to slide into and interact with the internal components of the tow socket **230**.

FIG. **4** illustrates a rear of the tow ball **305** facing a front of a tow ball receiver **405** for clocking and mating according to embodiments of the present disclosure. As shown, the rear of the tow ball **305** includes the rear cable interface **410** and multiple (for example, eleven) pin holes **415** (including pin holes **415***a*-**415***b*) within its rear truncated cone; and the 12 o'clock position of the rear truncated cone includes an unpierced portion between pin holes **415***a* and **415***b*. Correspondingly, the front of the tow ball receiver **405** includes the same number (for example, eleven) of pin holes **420** (including pin hole **420***a*) spaced apart from each other by a same interval of pin holes **415** of the tow ball **305**. When the pin hole **420***a* immediately beside the wedge notch cutout aligns with the pin hole **415***a*, the 12 o'clock position of the tow socket **230** is clocked into alignment with the 12 o'clock position of the tow ball **305**.

Dowel pins (shown in FIG. **7**B by reference number **745**) can be inserted into pairs of corresponding pin holes to establish accurate final alignment of the tow ball receiver **405** with the tow ball **305**. That is, one end of a dowel pin can be inserted into either the pin hole **415***a* or the pin hole **420***a* such that when the tow socket **230** and tow ball **305** are clocked into close alignment as a result of the cam follower in tow ball **305** moving the cam **230**, movement of the tow ball **305** toward the tow ball receiver **405** inserts the opposite end of the dowel pin into its mating pin hole (**415***a* or **420***a*). As such, the center longitudinal axis of each pin hole **415** can be substantially collinear with the center longitudinal axis of each corresponding pin hole **420**.

The rear cable interface **410** includes a threaded end **425** and a u-joint end **430**. The threaded end **425** is configured to threadedly attach to the protection/strength member/bend limiter of cable portion **205***c* of the tow cable **205**. The u-joint end **430** includes a u-joint end in contact with the rear truncated cone. The u-joint end **430** includes a pin about which the threaded end **425** pivotably attaches to the u-joint end **430**.

Although FIG. **4** illustrates one example of a clocking and mating hardware configuration between the tow ball **305** and tow ball receiver **405**, various changes may be made to FIG. **4**. For example, the relative sizes, shapes, and dimensions of the various components shown in FIG. **4** are for illustration only. Each component in FIG. **4** could have any other size, shape, dimensions, and number of connectors. As another example, other suitable clocking and mating configurations can be used, such as a ball and divot on mating surfaces.

FIG. **5** illustrates a longitudinal cross-section of an example tow ball **500** according to embodiments of the present disclosure. For ease of explanation, the tow ball **500** of FIG. **5** is described as being a component of the tow cable **205** that is used in the system **100** of FIG. **1**.

The tow ball **500** includes conductors **505** throughout its length, from the forward end to the rear end. The conductors **505** include an inner core of conductors **510** that carry power and signals to and from the receive array **150** in an aft direction. The inner core of conductors **510** includes multiple conductors, such as fiber optics for data communications. The inner core of conductors **510** passes through the tow ball **500** substantially along the center longitudinal axis of the tow ball **500**.

The conductors **505** include a layer of breakout conductors **515** that surround the inner core of conductors **510**, such as in a concentric manner. The power and signals transmitted to the transmitter of the leading towed body **200** is carried by the layer of breakout conductors **515**.

The tow ball **500** includes a plurality (e.g., eleven) of breakout connectors **520**. Each breakout connector **520** includes one end that connects to a corresponding conductor and another end that is disposed inside of a pin hole (e.g., pin hole **415** for making electrical contact with a connector in the tow socket **230**. In this longitudinal cross-sectional view, two breakout connectors **520** are shown, and each is connected to a breakout conductor **525** from the layer of breakout conductors **515**. Accordingly, inside of the tow ball, each breakout conductor **525** spreads apart from the inner core of conductors **510** to reach a corresponding breakout connector **520**. As shown, the tow ball **500** is pre-wired to the multiple (e.g., eleven) breakout connectors **520** within the tow ball **500** to mate with the same number of rotatable sleeve connectors in the tow socket **230**.

The tow ball **500** represents a portion of a single tow cable that further includes a protective/structural/bend limiting member **530** surrounding the layer of breakout conductors **515**, such as in a concentric manner. Member **530** can include multiple wires, such as steel wires, or other load bearing sleeving or U-joint components suitable for winching and with standing tension.

Like in FIG. **1**, the line C represents the location for the lateral cross-section of the single tow cable, and the circle with an "x" through the center represents a direction into the page for the cross-section cut along the line C.

FIG. **6** illustrates a lateral cross-section of an example tow cable **600** according to embodiments of the present disclosure. The tow cable **600** is a single cable that can be the same as or similar to the tow cable **110** or **205**. For example, the line C represents the location for the lateral cross-section of the tow cable **110**. The arrows attached to the line C represent a direction for the cross-section cut along the line C (i.e., the direction represented by the circle with an "x" through the center in FIGS. **1** and **5**). A lateral cross section of the second portion **205***b* of the tow cable **205** is similar to or substantially the same as a lateral cross section of the tow cable disposed inside of the forward end of the tow ball **305**, **500**.

The tow cable **600** includes three concentric layers, namely, an inner core of conductors (e.g., inner core of conductors **510**), an intermediate layer of breakout conductors, and a structural member forming an outer layer. In the example shown, the inner core includes six inner conductors **605** arranged in a circular manner surrounding a center conductor **610**. The center conductor **610** includes optical fibers configured to carry data communications. More particularly, the center conductor **610** carries a SONAR signals to and from the vessel **105**. In certain embodiments, the inner conductor **605** can have the same or similar function as the center conductors **610**. In certain embodiments, the center conductor **610** provides structure to the tow cable **110**.

In the example shown, intermediate layer of breakout conductors includes a plurality (e.g., eleven) of breakout conductors **615**. Each breakout conductor **615** is formed of an electrically conductive material, such as copper, and carries electrical power.

In the example shown, the outer layer structural member includes two sublayers of tension resilient wires. The outer layer includes wires **620** with a smaller diameter than the wires **625** of the penultimate layer.

Note that components **605** and **610** of the inner core, components **615** of the intermediate layer, and components **620**-**625** of the outer layer in FIG. **6** could be the same as or similar to corresponding components of the inner core of conductors **510**, components **525** of the layer of breakout conductors **515**, and the structural member **530** in FIG. **5**. These components in FIG. **6** can operate in the same or similar manner as the corresponding components in FIG. **5**.

Although FIG. **6** illustrates one example of a tow cable **600**, various changes may be made to FIG. **6**. For example, the relative sizes, shapes, and dimensions of the various components shown in FIG. **6** are for illustration only. Each component in FIG. **6** could have any other size, shape, and dimensions. As another example, the intermediate layer can include any suitable number of breakout conductors **615**, so long as the number matches the number of pin holes **415** in the tow ball **305**, **500** or number of pin holes **420** in the tow ball receiver **405**.

FIGS. **7**A and **7**B illustrate an example aft tow point socket **700** (hereinafter referred to as "tow socket") according to embodiments of the present disclosure. FIG. **7**A shows an assembly view of the tow socket **700**. FIG. **7**B shows an exploded view of the tow socket **700**. FIGS. **7**A and **7**B will be described together.

The tow socket **700** includes an outer housing **705**, a mount rail **710** on each side of the outer housing **705**, a front plate **715** fastened to a front of the outer housing, and other external components. The outer housing **705** extends from the front plate **715** to the back plate **735**. The tow socket **700** also includes internal components housed within the outer housing **705**. The internal components include a rotation sleeve **720**, a rotation cam **725**, the tow ball receiver **405** (shown in FIG. **4**), a thrust washer **730**, a back plate **735**, a guide cam **740**, dowel pins **745**, a slotted spring pin **750**, various fasteners, and other internal components. The slotted spring pin **750** limits the necessary cam action to a maximum rotation of about 180°.

The tow socket **700** could, for example, be used with the towing system **100** of FIG. **1** and the leading towed body **200**. Note that components **700**, **705**, and **715** in FIGS. **7**A and **7**B could be the same as or similar to corresponding components **210**, **235**, and **240** in FIG. **2**. These components in FIGS. **7**A and **7**B can operate in the same or similar manner as the corresponding components in FIG. **2**.

FIGS. **8**A and **8**B illustrate a solid assembly view of the tow socket **700** of FIG. **7** mounted to an aft tow point **805**. FIG. **8**A shows a perspective view of the tow socket **700**. FIG. **8**B shows a cross-sectional view of the tow socket **700**. FIGS. **8**A and **8**B will be described together. For ease of explanation, the tow socket **700** is described as being a component of the leading towed body **200** of FIG. **2**. Note that the aft tow point **805** could be the same as or similar to the aft tow point **225** in FIG. **2**.

As shown, the rotation sleeve **720** wedge cut out is on top and aligned with the wedge cut out of the outer housing **705**, which is the position for top-down cable entry into the center of the tow socket **700**.

The internal components of the tow socket **700** are arranged symmetrically about its longitudinal center axis and at various radial distances from the longitudinal center axis. The outer housing **705** forms an outer fixed sleeve that does not move relative to the aft tow point **805**. Multiple (e.g., two) low friction rings **810** are disposed between the rotation sleeve **720** and the internal surface of the outer housing **705** to enable the rotation sleeve **720** to rotate either clockwise or counterclockwise with low friction between the two surfaces. In certain embodiments, the low friction rings **810** are flush with the outer surface of the rotation sleeve **720** and do not extend radially outward beyond the outer circumference of the rotation sleeve **720**. The low friction rings **810** can be composed of material such as Teflon or nylon. Alternatively, surface treatments applied to the rotation sleeve **720** or inner surface of the outer housing **705** can provide low rotational resistance.

The guide cam **740** holds front low friction ring **810** in a fixed location relative to the front and back of the rotation sleeve **720**. That is, the guide cam **740** is fixed to an internal surface of the rotation sleeve **720**. The guide cam **740** is disposed radially within the rotation sleeve **720** in a same concentric layer as the rotation cam **725**. The guide cam **740** prevents the cam follower **345** on tow ball **305** from jamming when the tow cable **205** is not well aligned axially with socket assembly **700** prior to tow ball **305** insertion.

The tow ball receiver **405** forms the inner most concentric layer of the tow socket **700**. The inner circumference of the tow ball receiver **405** is sufficient for the inner core of conductors (e.g., inner core of conductors **510**) to pass through. In certain embodiments, the inner circumference of the tow ball receiver is wider than the outer circumference of the inner core (e.g., a conduit including the inner conductors **605**) by a clearance distance. Near the rear of the outer housing **705**, the rotation cam **725** is disposed radially between the tow ball receiver **405** and the rotation sleeve **720**. More particularly, the front of the tow ball receiver **405** that includes the entrance to the pin holes **420** has an outer circumference corresponding to the inner circumference of the rotation cam **725**. The tow ball receiver **405** extends in an aft direction from its front to a distance beyond the back plate **735**, and each pin hole **420** extends the entire length of the cylinder portion of the tow ball receiver **405**. The tow ball receiver **405** includes a flange near its front, and the flange protrudes radially outward from the outer circumference of the cylinder portion of the tow ball receiver **405**.

The fasteners **815** extend through and fasten the flange of the tow ball receiver **405** to the rotation sleeve **720**. Accordingly, the tow ball receiver **405** rotates together in unison with the rotation sleeve **720** while remaining in a fixed orientation relative to the rotation sleeve **720**.

The fasteners **820** extend through and fasten the rotation sleeve **720** to the rotation cam **725**. Accordingly, the rotation cam **725** rotates together in unison with the rotation sleeve **720** while remaining in a fixed orientation relative to the rotation sleeve **720**. That is, the rotation sleeve **720**, the rotation cam **725**, and the tow ball receiver **405** are fixed in orientation relative to each other and rotate as a unit.

Fasteners **825** extend through and fasten the back plate **735** to the outer housing **705**. Accordingly, the back plate **735** remains in a fixed orientation relative to the outer housing **705** and the aft tow point **805**.

The thrust washer **730** is disposed longitudinally between the back plate **735** and the rear face of the flange of the tow ball receiver **405**. The thrust washer **730** has an outer circumference substantially the same as the outer circumference of the rotation sleeve **720**, and has an inner circumference substantially the same as the outer circumference of the rear portion of tow ball receiver **405**.

Although FIG. **8** illustrates one example of a tow socket **700**, various changes may be made to FIG. **8**. For example, the relative sizes, shapes, and dimensions of the various components shown in FIG. **8** are for illustration only. Each component in FIG. **8** could have any other size, shape, and dimensions. As another example, the tow socket **700** could include flexible pigtails (shown in FIGS. **10**B and **11**B as reference number **1005**) from a back side of the tow ball receiver **405**.

FIG. **9** illustrates a method **900** of engaging an ABA according to embodiments of the present disclosure. For ease of explanation, the method **900** will be described as being implemented by the ABA **210**.

In block **905**, the tow socket **230** receives the tow cable **205** into the center of the tow socket **230**. More particularly, at the start of the method **900**, the wedge notch cutout at a top position that is approximately a 12 o'clock position. The wedge notch cutout of the internal components (i.e., rotation sleeve **720**, rotation cam **725**, and tow ball receiver **405**) are rotationally aligned with the wedge notch cutout of the outer housing **235** in order for the tow cable **205** to be lowered in the center. The third portion **205***c* of the tow cable **205** is initially above the tow socket **230**, and gets lowered into the wedge notch cutout of the outer housing **235** and internal components by an automated process.

In block **910**, the randomly-aligned tow ball **305** passes through the entrance of the tow socket **230**. That is, the tow socket **230** receives the tow ball **305** at the random orientation. More particularly, once the third portion **205***c* of the tow cable **205** is disposed within the center of the tow socket **230**, a winching operation moves the tow cable **205** such that the tow ball **305** moves in the aft direction.

In block **915**, the tow socket **230** rotates to rotationally align the tow socket pin holes **420** (including corresponding tow socket connectors therewithin) with the pin holes **415** (including corresponding breakout connectors **520**) of the tow ball **305**. More particularly, force of the cam follower **345** against the rotation cam **725** drives the rotation sleeve **720**, the rotation cam **725**, and the tow ball receiver **405** to rotate as a unit to a point of close final alignment. Final precision alignment occurs when two close-tolerance dowel pins **745** engage two (2) tow ball pin holes **415***a* with two (2) tow socket pin holes **420***a* prior to the connectors mating. That is, final precision alignment occurs when an opposite end of a dowel pin **745** that has one end disposed within the tow socket pin hole **420***a* enters the corresponding pin hole **415***a*.

In block **920**, the tow socket **230** mates (e.g., electrically couples) to the tow ball **305**. That is, conductors **420** within the tow ball receiver **405** each have connectors that form an electrical connection to the intermediate layer conductors **515** within the tow ball **500** through its corresponding connectors.

Although FIG. **9** illustrates one example of method of engaging an ABA **210**, various changes may be made to FIG. **9**. For example, while shown as a series of steps, various steps in FIG. **9** could overlap, occur in parallel, occur in a different order, or occur any number of times. As another example, a reverse order or the engagement process implements a disengagement process.

FIGS. **10**A through **12**C illustrate various operations within method of engaging an ABA in FIG. **9**. FIGS. **10**A and **10**B illustrate the operation of block **905** in FIG. **9**. FIG. **10**A illustrates the operation of block **905** from a point of view looking at a forward or front face of the tow socket **230** in the aft direction. FIG. **10**B illustrates the operation of block **905** from a point of view looking at the rear face of the tow ball receiver **405** of tow socket **230** in the forward direction **130**. The tow ball **305** is outside of and forward of the tow socket **230** according to the forward direction **130**. The tow ball orientation is initially random relative to the orientation of the tow socket **230**. The tow ball connectors are keyed to the cam follower **345**, while the tow socket connectors are keyed to the rotation cam **725** and rotation sleeve **720**. The flex cable **1005** has slack to rotate clockwise or counter clockwise. The flex cable **1005** provides a connection from the towed body to the rotating sleeve.

FIGS. **11**A and **11**B illustrate the operation of block **910** in FIG. **9**. FIG. **11**A illustrates the operation of block **910** from a point of view looking at a forward or front face of the tow socket **230** in the aft direction. FIG. **11**B illustrates the operation of block **910** from a point of view looking at the rear face of the tow ball receiver **405** of the tow socket **230** in the forward direction **130**. The cam follower **345** makes surface-to-surface contact with the internal surface of the rotation cam **725**, forcing the rotation sleeve **720** to rotate clockwise or counterclockwise based on whether the cam follower **345** contacts a right or left side of the rotation cam **725**. In the example shown, the cam follower **345** protrudes leftward (looking aft) as it contacts the left side of the rotation cam **725**, and as a result, the tow ball receiver **405** rotates counterclockwise (looking aft).

FIGS. **12**A, **12**B, and **12**C illustrate the operation of block **920** in FIG. **9**. FIG. **12**A illustrates the operation of block **920** from a point of view looking at a forward or front face of the tow socket **230** in the aft direction. FIGS. **12**B and **12**C illustrates the operation of block **920** from a point of view looking at the rear face of the tow socket **230** in the forward direction **130**, wherein the flex cable **1005** wraps clockwise and counterclockwise, respectively. The aft end of the tow ball **305** bears on the tow ball receiver **405** of tow socket **230** as a result of tension on the third portion **205***c* of the tow cable. The flex cable **1005** wraps zero to 180° in the clockwise or counter clockwise direction.

While this disclosure has described certain embodiments and generally associated methods, alterations and permutations of these embodiments and methods will be apparent to those skilled in the art. Accordingly, the above description of example embodiments does not define or constrain this disclosure. Other changes, substitutions, and alterations are also possible without departing from the spirit and scope of this disclosure, as defined by the following claims.

Modifications, additions, or omissions may be made to the systems, apparatuses, and methods described herein without departing from the scope of the invention. The components of the systems and apparatuses may be integrated or separated. Moreover, the operations of the systems and apparatuses may be performed by more, fewer, or other components. The methods may include more, fewer, or other steps. Additionally, steps may be performed in any suitable order. As used in this document, "each" refers to each member of a set or each member of a subset of a set.

What is claimed is:

1. A system comprising:

a body comprising a tow socket configured to receive a randomly-aligned tow ball, the tow socket having a rotatable sleeve, a cam, and multiple mating connectors, each mating connector electrically coupled to an electrical conductor; and

a cable configured to be coupled to the body in order to facilitate towing of the body, the cable comprising multiple core connectors and multiple breakout connectors configured to transport signals,

wherein the cable further comprises a tow ball configured to enter the rotatable sleeve of the tow socket, the tow ball comprising connectors configured to couple the breakout connectors of the cable to the mating connectors of the tow socket,

wherein the cam is coupled to the rotatable sleeve and configured to rotate the rotatable sleeve to substantially align the mating connectors of the tow socket with connectors of a tow ball such that each electrical conductor electrically coupled to a mating connector couples to a corresponding connector of the tow ball.

2. The system of claim **1**, wherein the tow socket further includes a fixed sleeve within which the rotatable sleeve is configured to rotate.

3. The system of claim **2**, wherein the fixed sleeve is configured to fixedly attach to the body.

4. The system of claim **1**, wherein the cam is further configured to rotate according to a force from physical contact between the cam and cam follower of the tow ball.

5. The system of claim **1**, wherein the connectors of the tow ball are configured to pass through electrical conductors and optical conductors.

6. That system of claim **1**, wherein the cable includes a structural member and electrical conductors arranged concentrically.

7. The system of claim **1**, wherein the tow ball is disposed at a mid-point of the cable.

8. The system of claim **1**, wherein the tow socket further comprises:

a slot configured to receive the cable into the rotatable sleeve, and an entrance through which the tow ball enters the rotatable sleeve,

wherein the slot is arranged perpendicular to the entrance.

9. The system of claim **1**, wherein movement of the cable transfers a tow loading force between the cable and the tow socket.

10. An apparatus comprising:

a tow socket configured to receive a randomly-aligned tow ball, the tow socket having a rotatable sleeve, a cam, and multiple mating connectors, each mating connector electrically coupled to an electrical conductor,

wherein the cam is coupled to the rotatable sleeve and configured to rotate the rotatable sleeve to substantially align the mating connectors of the tow socket with connectors of a tow ball such that each electrical conductor electrically coupled to a mating connector couples to a corresponding connector of the tow ball.

11. The apparatus of claim **10**, further comprising a fixed sleeve within which the rotatable sleeve is configured to rotate.

12. The apparatus of claim **11**, wherein the fixed sleeve is configured to fixedly attach to a body.

13. The apparatus of claim **10**, wherein the cam is further configured to rotate according to a force from physical contact between the cam and cam follower of the tow ball.

14. The apparatus of claim **10**, wherein the rotatable sleeve is configured to receive the tow ball through an entrance.

15. The apparatus of claim **10**, wherein the apparatus is fixedly attached to a body to be towed, and

wherein the tow ball is a component of a cable that is configured to be coupled to the body in order to facilitate towing of the body, the cable comprising multiple core connectors and multiple breakout connectors configured to transport power and signals.

16. The apparatus of claim **10**, wherein movement of the cable transfers a tow loading force between the cable and the tow socket.

17. A method comprising:

receiving, by a tow socket having a rotatable sleeve and multiple mating connectors, a cable into the tow socket through a slot, wherein the cable comprises a tow ball, and wherein each mating connector is electrically coupled to an electrical conductor;

receiving, by the rotatable sleeve, the tow ball through an entrance;

rotating a cam to rotate the rotatable sleeve to substantially align the mating connectors of the tow socket with connectors of the tow ball such that each electrical conductor electrically coupled to a mating connector couples to a corresponding connector of the tow ball; and

transferring a tow loading force between the cable and the tow socket by moving the cable.

18. The method of claim **17**, wherein the cam is further configured to rotate according to a force from physical contact between the cam and cam follower of the tow ball.

19. The method of claim **17**, further comprising coupling the connectors of the tow ball with the mating connectors of the tow socket.

20. The method of claim **17**, wherein the slot is arranged perpendicular to the entrance.

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